Introduction: The History, Purpose and Content of the Springer *International Handbook of Research in History, Philosophy and Science Teaching* (Springer 2014)

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This is the first Handbook to be published that is devoted to the field of historical and philosophical research in science and mathematics education (HPS&ST). Given that science and mathematics through their long history have always been engaged with philosophy and that for over a century it has been recognised that science and mathematics curriculum development, teaching, assessment and learning give rise to so many historical and philosophical questions, it is unfortunate that such a Handbook has been so long coming.

This work is an international endeavour with its 75 chapters being written by 125 authors from 30 countries. Each chapter has benefited from reviews by up to six scholars and has undergone multiple revisions. More than 300 reviewers, from the disciplines of history, philosophy, education, psychology, mathematics and natural science were willing to contribute their time and expertise to the project. Volunteer copyeditors, with command of both the subject area and English expression, also contributed to the final form of the chapters. A great debt is owed by authors, the research community and readers to these reviewers and copyeditors for their anonymous and unrewarded work. The Handbook has grown directly from the Springer journal *Science & Education: Contributions from History and Philosophy of Science and Mathematics.*[1]

The International History, Philosophy and Science Teaching Group

The journal in turn is associated with the International History, Philosophy and Science Teaching Group that held its first conference in 1989 at Florida State University, with subsequent conferences held biennially.[2] The conferences are attended by historians, philosophers, cognitive psychologists, scientists, mathematicians, education researchers and teachers all of whom have contributed greatly to the formation of a vibrant, congenial, multidisciplinary, international research community. This community forms the core of the authors and reviewers for the Handbook; the Handbook is a concrete expression of the interests and scholarly work of this community.

The structure, contents and rationale of the Handbook have a lineage that goes back to the very beginnings of the IHPST group and thus there is benefit in giving an account of its

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[1] The journal was the first such research journal devoted exclusively to HPS-informed research in science and mathematics education. Thirty of the contributors to the Handbook are on the Editorial Committee of the journal; nearly all of the 125 authors have published in the journal; and the 300+ reviewers have been drawn from the journal's pool of 800+ reviewers (these can be seen at http://ihpst.net/journal/reviewers/list-of-reviewers/). But the century of research covered by the contributors extends far beyond the pages of the journal, as can be seen by looking at the Reference lists of the chapters.

[2] These have been: Queen's University Kingston (1992), University of Minnesota (1995), University of Calgary (1997), University of Pavia (1999), Denver (2001), University of Manitoba (2003), University of Leeds (2005), University of Calgary (2007), University of Notre Dame (2009), Aristotle University Thessaloniki (2011) and University of Pittsburgh (2013). Since 2010 these international conferences have been augmented by regional conferences in Latin America: Maresias Beach, Brazil in 2010, Mendoza Argentina (2012); and Asia: Seoul National University (2012), National Taiwan Normal University (2014).

early history. In 1987 I took sabbatical leave at the Philosophy Department of Florida State University in order to pursue with David Gruender some research on Galileo's pendulum discoveries. While in Tallahassee, I attended a large Newton-celebration sponsored by the AAAS to honour the tri-centenary of the publication of Newton's *Principia*. Returning from that Washington meeting I casually mentioned to Jaakko Hintikka that 'it is a pity that science teachers do not attend such meetings, there was so much there that would have been of interest and use to them'. In response Hintikka, the editor of *Synthese* the major Kluwer philosophy of science journal, suggested that I edit a special issue of journal on the subject of 'History, Philosophy and Science Teaching' (HPS&ST). This casual exchange was to be the seed of the IHPST group, the journal *Science & Education,* and 25 years later this Handbook.

I began writing, at a time before email and the web, to scholars I knew who had HPS&ST interests and asking them to send me names of others they knew; this was a sort of academic 'pyramid' scheme. The result was a very large and impressive collection of manuscripts written by historians, philosophers, scientists, cognitive scientists and educators.[3] With far too many manuscripts for a single issue of *Synthese* I reached agreement with other journal editors to publish eight special issues of different journals devoted to the subject. These together constituted the first ever journal issues with the title 'History, Philosophy and Science Teaching'.[4]

David Gruender, and Ken Tobin who was newly appointed to Science Education at Florida State University, suggested bringing authors and readers together for an HPS&ST conference. The resulting meeting, with the generous support of the National Science Foundation and of Florida State University, was held in November 1989. There were 180 participants including nearly all of the above listed journal contributors. Two large volumes of Proceedings – *The History and Philosophy of Science in Science Teaching,* edited by Don Herget and containing 75 papers - were produced.[5] Others gave papers or contributed to the conference.[6]With the special issue articles, the *Proceedings*, and other papers, there was an abundance of material with which participants could engage.

Fortunately in the process of 'networking' for the conference contact was made with Fabio Bevilacqua from the University of Pavia and who was chairman of the Interdivisional

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[3] Among those who contributed manuscripts were: Joan Solomon, Rodger Bybee, Manuel Sequeia, Laurinda Leite, Harvey Siegel, Martin Eger, Nancy Nersessian, Ernst von Glasersfeld, Joseph Pitt, Jim Garrison, Ian Winchester, Michael Ruse, Arthur Stinner, James Cushing, Stephen Brush, Arnold Arons, Michael Otte, Dimiter Ginev, Derek Hodson, Fritz Rohrlich, Mansoor Niaz, George Kauffman, Pinchas Tamir and Wim van der Steen.

[4] The journals were: *Educational Philosophy and Theory* 20(2), (1988); *Synthese* 80(1), (1989); *Interchange* 20(2), (1989); *Studies in Philosophy and Education* 10(1), (1990); *Science Education* 75(1), (1991); *Journal of Research in Science Teaching* 29(4), (1992); *International Journal of Science Education* 12(3), (1990); *Interchange* 24(1-2), (1993).

[5] The *Proceedings* included papers written by, among others: Sandra Abell, Angelo Collins, Jere Confrey, George Cossman, Zoubeida Dagher, Peter Davson-Galle, Arthur Lucas, Michael Akeroyd, James Gallagher, Teresa Levy, Richard Duschl, Thomas Settle, Hugh Petrie, Robert Hatch, Jane Martin, Joseph Nussbaum, Stellan Ohlsson, Luise Prior McCarty, Edgar Jenkins, Jacques Désautels, Marie Larochelle, Thomas Wallenmaier, Alberto Cordero, Sharon Bailin, Jim Stewart, and Carolyn Carter.

[6] Among these were: Peter Slezak, Robert Carson, Douglas Allchin, Judith Kinnear, Michael Clough, Hans O. Anderson, Penny Gilmer, Richard Grandy, Jack Lochhead, Zofia Golab-Meyer, James Wandersee, Matilde Vicentini, Peter Taylor, Brian Woolnough and Joseph Novak.

Group on History of Physics of the European Physical Society.[7] Although from a Physics Department, Bevilacqua had completed his PhD in the History and Philosophy of Science Department at Cambridge University, with a thesis supervised by Mary Hesse and Gerd Buchdahl.

The European Group's Pavia conference was held under the auspices of the International Commission on Physics Education (ICPE) and it explicitly tried to build on an earlier ICPE conference (1970) on 'History in the Teaching of Physics' whose published Proceedings were edited by Stephen G. Brush and Allen L. King. The 1983 Pavia conference organisers, Fabio Bevilacqua and Peter Kennedy, wrote in the *Pavia Conference Proceedings* that 'we began to feel that to confine the discussion only to the history of physics was unduly restrictive and that philosophy and sociology had much to contribute in seeking to show a more complete picture of physics'. From the beginning the IHPST group had the same conviction but applied to all the sciences.

Bevilacqua attended the Tallahassee meeting (and is remembered for his commanding role as the scarlet-cloaked Cardinal Bellarmine in Joan Solomon's conference production of 'The Trial of Galileo' in which Michael Ruse is remembered for his Galileo performance). Connection with the European group contributed greatly to making IHPST less a US-Anglo grouping and more robustly an international group. On account of the uncommon spread of disciplines represented and its conviviality, Tallahassee was an overwhelmingly successful and much-remembered meeting. The participants constituted an informal IHPST group for which I became the newsletter editor.

There are many things that can be said about the background and deliberations of the Tallahassee meeting. The first is that although the bulk of the conference was concerned with the traditional liberal education agenda of how HPS can enhance and improve the teaching of science, it did occur at the same time as the 'Science Wars' were erupting in the HPS and Science Studies communities; it was an intellectually exciting and polarising time. The wars erupted on many fronts - in sociology of science, the Edinburgh 'Strong Programme' was gaining academic traction fuelled in part by relativist and constructivist interpretations of Thomas Kuhn; many feminist and multicultural critiques of science and of orthodox philosophy of science had been published; postmodernist outlooks were being manifested in many departments.[8]

To some degree the Science Wars, Postmodernism, and Realist versus Constructivist debates were played out at the conference. A plenary session was devoted to the Constructivist debate; it was chaired by Ken Tobin and contributed to by Jaques Désautels, Ernst von Glasersfeld and David Gruender. Grunder's paper was titled: 'Some Philosophical Reflections on Constructivism', and he wrote: 'It is impossible to look at current literature dealing with the education of teachers, especially in science and mathematics, without noticing the galvanizing effects of the newly introduced theory of "constructivism"'. He

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[7] The European group had already held education conferences in Pavia (1983), Munich (1986) and Paris (1988). Subsequently it would hold conferences in Cambridge (1990), Madrid (1992), Szombathely (1994), Bratislava (1996) with printed Proceedings being produced for each of these meetings. In 1999 the Group's conference was held jointly with the IHPST conference in Pavia and Lake Como.

[8] By the time of the conference, the work of Jean-Francǫis Lyotard, Michel Foucault, Michael Mulkay, Bruno Latour, Harry Collins, Sandra Harding, Evelyn Fox Keller, Andrew Pickering, David Bloor, Michael Lynch, Steve Woolgar, Donna Haraway, Sal Restivo, Mary Belenky and Jacques Derrida had been published, much read, and having some influence on theorists in education circles. Ernst von Glasersfeld, the 'radical constructivist', was an energetic participant at the conference, and a contributor to the *Synthese* special issue.

went on to caution that: 'this whole approach of defining knowledge in terms of environmental feedback leading to constructs which better enable the knower to survive in the environment raises serious theoretical issues of its own. And this is so whether one prefers the version offered by Piaget or by Dewey'.

There were divisions at the conference about the epistemological, ontological and pedagogical merits of constructivism, a division between two intellectual tendencies, loosely labelled Realism and Constructivism, yet very pleasingly the conference was marked by convivial and congenial exchanges on the subject. There was wide agreement about the benefit of constructivist pedagogy, but disagreement about its commonly related epistemological and ontological claims. This tension has carried through the subsequent history of the group and the journal. For the journal debate began with Wallis Suchting's severe paper 'Constructivism Deconstructed' and Ernst von Glasersfeld's 'Reply' both in the first volume (1992), and continued through a special double-issue on the subject in the sixth volume (1997), and into subsequent volumes right through to the present Handbook chapter.

A second noteworthy thing about the Tallahassee conference and in the collection of journal special-issues is the part played by cross-disciplinary training of individuals involved. In particular the conference and journal special issues came about because an Italian Physics lecturer had completed a HPS degree at Cambridge, and an Australian Education lecturer had completed a philosophy degree at the University of Sydney, and had taken sabbatical leave in the FSU Philosophy department. Other participants had comparable cross-disciplinary backgrounds. For everyone the value of scientists and science and mathematics educators working with philosophers, historians, cognitive psychologists and others was immediately apparent.

The value of cross-disciplinary training, or at least cooperation, was a lasting lesson that has informed the subsequent history of IHPST, the journal *Science & Education,* and 25 years later, the organisation of this handbook. It is a lesson that perhaps should inform the training and preparation of science educators where too often the standard trajectory is Science followed by Education and then educational research without mastering any other foundation discipline such as Philosophy, Psychology, History or Sociology.

After twenty years of productive but informal existence without office bearers, the group was formalised in 2007 at its Calgary conference. A constitution was adopted, elections for a governing council were held, and the following aims adopted:

> **(a)** The utilization of historical, philosophical and sociological scholarship to clarify and deal with the many curricular, pedagogical and theoretical issues facing contemporary science education. Among the latter are serious educational questions raised by Religion, Multiculturalism, Worldviews, Feminism, and teaching the Nature of Science.
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> **(b)** Collaboration between the communities of scientists, historians, philosophers, cognitive psychologists, sociologists, and science educators, and school and college teachers.
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> **(c)** The inclusion of appropriate history, philosophy, and sociology of science courses in science teacher-education programmes.
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> **(d)** The dissemination of accounts of lessons, units of work, and programmes in science, at all levels, that have successfully utilized history, philosophy, and sociology.
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> **(e)** Discussion of the philosophy and purposes of science education, and its contribution to the intellectual and ethical development of individuals and cultures.

The Handbook contributes to realising these aims.

Science & Education Journal

The journal began during a conversation at a US Philosophy of Education conference in 1990 with Peter de Liefde, then Kluwer Education Editor. Kluwer did not then have a presence in science education and he saw the possibility of building on the IHPST newsletter and community in creating a new scholarly journal. With a great deal of assistance from many people who agreed to be on the Editorial Committee, the journal commenced publication in 1992. In its beginnings the journal tried to meet the highest standards; pleasingly it was able to publish research by deservedly well-known scholars from the fields of science education, mathematics education and history and philosophy of science.[9] It is no exaggeration to say that the disciplinary spread and quality of authors had not before been seen in education journals. The multi-disciplinary pattern and high standards were maintained in the following twenty-plus years where well-known scholars have been published who may not otherwise have addressed issues in science and mathematics education.[10]

Since its beginning in 1992 with four numbers per year, the journal has grown both in size and in scholarly recognition. In 1997 it moved to six numbers, in 2003 to eight numbers and in 2007 to ten numbers per volume; in 2011 there were 108,650 article-downloads from its Springer site.

The Handbook Project

The Handbook project began in 2010 during discussion with Bernadette Ohmer, the Springer Education Editor (Springer having taken over Kluwer in 2005) about how best to celebrate the 20th anniversary of the founding of *Science & Education*. It was soon obvious to both of us that a HPS and Science Teaching Handbook was the best and most useful way to mark the journal's publication milestone. This began the three year process of contacting, inviting, structuring, writing, reviewing, revising, more reviewing and writing that has led to the 2013 publication of the Handbook.

For the historic record and for understanding the contents of the Handbook, it is worth repeating the initial invitation to authors:

> The guiding principle for the *Handbook* chapters is to review and document HPS-influenced scholarship in the specific field, to indicate any strengths and weaknesses in the tradition of research, to draw some lessons from the history of this research tradition, and to suggest fruitful ways forward. … The expectation is that the handbook will demonstrate that HPS contributes significantly to the understanding and resolution of the numerous theoretical, curricular and pedagogical questions and problems that arise in science and mathematics education.

Authors accepting the invitation to contribute received a reply saying:

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[9] In the first year papers by, among others, Wallis Suchting, Paul Kirschner, Mark Silverman, Derek Hodson, Martin Eger, Helge Kragh, Maryvonne Hallez, Israel Scheffler, Alberto Cordero, Creso Franco and Dominique Colinvaux-de-Dominguez were published. In the second year papers by, among others, Richard Kitchener, Gerd Buchdahl, Jack Rowell, Walter Jung, Henry Nielsen, Harvey Siegel, Lewis Pyenson, Victor Katz, Bernard Cohen, Nancy Brickhouse and Enrico Giannetto. The third year saw papers, by among others, John Heilbron, Peter Machamer, Michael Martin, Robert S. Cohen, Peter Slezak, Andrea Woody, James Garrison and Jane Martin. A number of these papers had their origins in conferences of the conferences of the Interdivisional Group on History of Physics of the European Physical Society.

[10] Philosophers who have published in the journal include: John Worrall, Alan Musgrave, Hasok Chang, Peter Machamer, Michael Martin, Noretta Koertge, Robert Crease, Patrick Heelan, Robert Nola, Alan Chalmers, Mario Bunge, Robert Pennock, Steve Fuller, Jane Roland Martin, Howard Sankey, Demetris Portides, Hugh Lacey, Gürol Irzik, Cassandra Pinnick, Joseph Agassi, Michael Ruse, David Depew, Massimo Pigliucci and many more. Historians whose work has been published have included: John Heilbron, Lewis Pyenson, Roger Stuewer, William Carroll, Stephen Brush, Roberto de Andrade Martins, Bernadette Bensaude-Vincent, Ronald Numbers, John Hedley Brooke, Diane Paul and many more.

> The expectation is that [the Handbook] will make the history and philosophy of science (and mathematics) a more routine and expected part of science and mathematics teaching, teacher education and graduate research programmes.
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> My own view is that much the same arguments developed in the handbook will apply to teaching and research in any discipline – economics, history, geography, psychology, theology, music, art, cognitive science, literature and so on. That is, to educate someone in any discipline requires a grasp of the history and philosophy of the discipline; and to conduct serious research in the teaching and learning of any discipline will likewise require historical knowledge and philosophical competence. Hopefully this handbook might inspire others to repeat the exercise for other disciplines.

It will be for readers to judge how significant the Handbook's contribution is to science and mathematics education. Readers will have their own view on whether teaching a subject requires some knowledge of the history and philosophy of the subject; and they will also have their own view on the degree to which research in the teaching and learning of science and mathematics requires historical and philosophical competence. Handbook authors affirm both positions. If their arguments are convincing, then they have clear implications for teacher education and for doctoral programmes that prepare education researchers.

Handbook Structure

Focussed discussion of HPS&ST questions was given a significant boost in the nineteenth century when Ernst Mach, the great German physicist, philosopher, historian and educator, founded in 1887 the world's second science education journal - *Zeitschrift für den physikalischen und chemischen Unterricht*.[11] In the US, John Dewey in the 1920s explicitly addressed HPS&ST issues, later taken up in the 1950s and 1960s by, among others, James Conant, Gerald Holton, Stephen G. Brush, Leo Klopfer, Robert S. Cohen, Joseph Schwab and Arnold Arons. In the UK, HPS&ST issues were addressed from the 1920s in books and articles by Frederick Westaway, Eric Holmyard and James Partington; and subsequently by John Bradley, Joan Solomon and others. The same questions have been investigated in Spanish, Portuguese, French, German, Italian, Finnish and other traditions. So there is an abundance of material to be covered and appraised in an HPS&ST handbook.

The first question in putting the Handbook together was how to structure its contents. My choice was to group extant research into four sections:

Pedagogical Studies
Theoretical Studies
Regional Studies
Biographical Studies

The Pedagogical section was straightforward. Since Mach's time, educators have looked to history and philosophy in order to improve and make more interesting and engaging the classroom teaching of science and mathematics. Curriculum writers have likewise turned to the history and philosophy of both disciplines for guidance about the philosophical structure and epistemology of the subjects, and suggestions about the best order, from a psychological or maturation perspective, in which to present the subjects. For over a century these endeavours have been pursued in Physics, Chemistry, Biology, Mathematics, and more recently in the Earth Sciences, Astronomy, Cosmology and Ecology. Since, for instance, the 1920s HPS-informed articles have appeared in *The Journal of*

[11] The first such journal was *Zeitschrift für mathematischen und naturwissenschaflichen Unterricht* which began publication in 1870. It was edited by J.C.V. Hoffmann, a secondary school teacher in the Saxony mining town of Freiberg (thanks to Kathryn Olesko for this information).

Chemical Education, The School Science Review and *Science Education*; they might also be found at this early time in *The American Journal of Physics* and *Physics Education*.

The research literature on HPS and physics teaching is voluminous. This is perhaps to be expected given that Ernst Mach is the founder of formal, organised, published HPS&ST research, and that all of the prominent physicists of the nineteenth and twentieth centuries were, like Mach, engaged by philosophy and wrote books on the subject. Handbook chapters cover each of the areas of Mechanics, Optics, Electricity, Relativity, Quantum theory, Energy and Thermodynamics. One need only mention these science fields to be reminded that major historical figures contributed to their development, and in each there were, and still are, serious philosophical issues and controversies. The specific case of Pendulum Motion is included as an example of how the understanding and teaching of even mundane areas of science can be illuminated and energised by knowledge of the history and philosophy of topic.

For over a century there has been insightful writing on the history of chemistry, and of course on some of the major advances and controversies in the discipline such as the phlogiston versus oxygen theory of combustion, formulation of the periodic table, uncovering of atomic structure and resultant theory, and organic compounds and their creation. Much has been written on the work of Priestley, Lavoisier, Dalton, Mendeleev, Davy, Kehulé, Pauling and other major contributors. There has also been a long history, since Edward Frankland and Henry Armstrong in the nineteenth century and Eric Holmyard between the wars, of serious efforts to utilise the history of chemistry in creating chemistry curriculum and improving chemistry teaching. Two chapters here deal with this research. In contrast, philosophers have not paid the same attention to chemistry, but over the past three decades this has changed, and there is now at least one journal dedicated to the subject, *Foundations of Chemistry*, and there have been important books published in the field. Philosophy was mostly implicit in the long decades of utilising history in chemistry education; it was made explicit in the 1960s by John Bradley, the Machian chemist, in his debates with Nuffield Scheme 'atomic modelists'. In this debate he lamented that: 'The young people of this country come hopefully to school asking for the bread of experience; we give them the stones of atomic models'.[12] Pleasingly a Handbook chapter deals with the now more conscious efforts to explicate philosophy of chemistry, and to connect this with issues in chemistry education.

History and philosophy have a far more public face in the teaching of biology, this is especially so for the teaching of evolution and of genetics, and four Handbook chapters devoted to these topics. Macroevolution, or the evolution of new species, has been seen since Darwin as a difficult biological problem, and one that has philosophical overtones. The philosopher Karl Popper famously asserted that the core Darwinian thesis - natural selection operates to separate the best adaptations in an environment – far from being a scientific insight is simply non-scientific as it is a hollow tautology (the best adapted species means that it is the species that survives). And the whole question of creation of new species demands a definition of species, something that is harder to do than it sounds. Can such definitions be given without recourse to Aristotelian essentialism? Leaving aside the powerful religious and cultural constraints in learning evolution, there are well documented psychological constraints to mastery of the theory. The foremost of these is deep-seated, in-born, teleological mental outlooks that we all have; the animal and even vegetable world are

[12] *The School Science Review*, 1964 vol. 45, p.366. Obviously teachers require some understanding of debates about instrumentalism, realism and positivism to appreciate Bradley's charge.

understood as intentional and goal-driven. This is a basic Aristotelianism that is close to the surface in Lamarckian accounts of evolution and on the surface of many culture's understanding of the natural world. This is something against which Darwin struggled, and it is inside the heads of all students. The two Evolution chapters deal with, among other things, this range of questions.

One of the genetics chapters establishes that it is a very difficult subject to teach, and discusses how the history of genetics is related to important philosophical issues such as: reductionism, genetic determinism and the relationship between biological function and structure. The chapter documents empirical studies where HPS considerations can improve the teaching and learning of the subject. The second genetics chapter reports results on how ideas about genes and gene function are treated in textbooks and appear in students' views; it also reports on a teaching strategy for improving students' understanding of scientific models in genetics.

HPS has contributed to the sciences of ecology, astronomy and geology. The Handbook chapters on these fields of study appraise the large bodies of research that have appealed to HPS for their better teaching and better student learning. In the cosmology chapter we are reminded that the subject differs in some respects significantly from other sciences, primarily because of its intimate association with issues of a conceptual and philosophical nature. Because cosmology in the broader sense relates to the students' world views, it provides a means for bridging the gap between the teaching of science and the teaching of humanistic subjects; and clearly philosophical matters of time, causation and creation are germane for any informed teaching and learning of the subject.

It is worth drawing attention to the inclusion of mathematics in this first section. Unfortunately science education handbooks too often ignore research in mathematics education. In the editorial of the first number (1992) of *Science & Education* I wrote that: 'One major division that *Science & Education* seeks to overcome is that between researchers in mathematics education and researchers in science education. Seldom, particularly in the Anglo world, do these two groups meet or read each-others' work … The history and philosophy of science and of mathematics are interwoven disciplines, they are a natural vehicle for bringing the two communities together. Many problems in science education have their origins in the quantitative side of science, and many problems in mathematics education have their origins in the supposed irrelevance of mathematical formalism.' (p.2) Science cannot be done without mathematics, and science even from the earliest ages cannot be learnt without learning relevant mathematics; so the divorce between the two research communities is unfortunate and ultimately to the detriment of teachers and learners. The seven mathematical papers in this Handbook flesh out this claim, and appraise aspects of the long tradition of HPM&MT scholarship.

Many topics included in the theoretical section were straightforward; they were obvious choices. Science teachers, curriculum writers, examiners and textbook authors clearly have to address larger philosophical matters about, for example: religion, multiculturalism, indigenous knowledge systems, nature of science, scientific method and inquiry, argumentation, constructivism, evolution education, postmodernism, scientific literacy, and the relation of science to personal and cultural worldviews. And where such questions are not addressed educators frequently need to justify their failure to do so.

Issues, for instance, about teaching and assessing the nature of science have been put on national curricular and assessment tables across the world. These NOS matters are so extensive and the research so voluminous that they are addressed in three papers. The same applies to religion where religious tradition have centuries of engagement with science and

science education; and so of course does atheism. Seven papers in the Handbook deal with these bodies of research and debate. There are also chapters on how the HPS&ST tradition connects to the science-technology-society (STS) tradition and more recently the cultural studies tradition in education. Examination of these connections and divergences benefits from historical and philosophical elaboration.

Other theoretical topics might not be so apparent, but nevertheless they are important; they have historical and philosophical dimensions, and are covered in Handbook chapters. All involved in science and mathematics education need to understand then explain core features of the subject they are teaching: what scientific explanation is, what laws are, what scientific method is or is not, what proof is, what models are, how values enter or do not enter scientific investigation and decision making, how thought experiments have functioned in science and can function in classrooms, and so on. Handbook contributions discuss these topics and research on how they are best taught.

Also discussed is the topic of student learning and how research on it can be illuminated by philosophy. Many, following Dewey and Piaget have pointed out that the psychology of learning and the epistemology of what is learnt need to be better connected. One of the biggest fields in science education research over the past four decades has been conceptual change research, yet in the famous foundational 1982 article by Posner and associates, they point out that they are proposing a theory of *rational* or *reasonable* conceptual change and assuredly the promotion of rationality and reasonable thinking is at least one aim of science education. Once this is appreciated, then it is clear that historians and philosophers can fruitfully be involved with educators; investigating rationality, its shades and alternatives, is central to their disciplines.

Likewise when cognitive scientists say that knowledge is 'what can be retrieved from long-term memory' philosophers can draw on the long history of epistemology to point out serious problems with this formulation: not everything remembered is knowledge, and claims are not knowledge because they are remembered; other things are involved. Since Plato established that merely true belief is not knowledge, philosophers have discussed the 'other things' involved. Cross-disciplinary engagement between educators, psychologists and philosophers is the way forward here. The conceptual change and Wittgenstein chapters appraise research in this field.

Narrative teaching, informal learning and the long tradition of 'historical investigative teaching' which is based on student 'reproduction' of classical experiments and engagement in the debates occasioned by these experiments – all give rise to philosophical questions and can be illuminated by historical studies. Everyone recognises that without science teaching, there would be no science, but this core reality is oft left unexamined. The chapters here on the role of textbooks in instruction, and on the attention given, and not given, to science education by historians of science examine the literature and arguments on this nexus between science and science teaching.

One of the most important elements that guided the development of the Handbook, that energised *Science & Education* journal, and that fostered a good deal of the century-plus of HPS&ST writing and research is an underlying conviction about what science and mathematics education should be; that is, what personal and social goals they should pursue, what kind of teaching and assessment is appropriate, what curriculum is justified, and so on. When spelt out this amounts to an underlying philosophy of science and mathematics education. What has animated this work is a conception of *liberal* education, but such an idea needs to be elaborated and defended against alternatives. Philosophy of education is the discipline where, since Mach and Dewey, these debates have occurred; it is a discipline with

which teachers need to engage. Without doubt the most formative influences on my own teaching and educational engagements was the work of the philosophers of education Richard Peters and Israel Scheffler; with some of Peters' arguments being the 'most practical' thing I learnt in my teacher education programme.

Fortunately the Handbook includes a chapter detailing and appraising the fruits of this long connection of philosophy of education with practical and theoretical issues in science and mathematics education. The specific chapter, and more broadly the 34 papers in the Theoretical section, of the Handbook provide evidence for the usefulness of having Philosophy or other Foundation studies included in teacher education programmes, and for researchers having them included in doctoral programmes. As has been pointed out, without such exposure or training, educators too often adopt 'slogan like' positions in philosophy, psychology and sociology.

Having a regional studies section in the Handbook was also straightforward. HPS&ST issues and associated research have occupied teachers and educators in many countries. By detailing for selected countries and regions these debates and research something can be gleaned about the international extent of concern about the place of history and philosophy, or nature of science, in science teaching; and the particular ways in which teachers, academics and educational administrators in different countries have responded to this concern. The US, England and Brazil have had the longest and most public engagement with these issues, and have generated the most public and scholarly argument. Other countries have had similar debates and their history is discussed here. Of particular note is the inclusion of chapters dealing with how HPS&ST questions have been addressed in three Asian countries - Japan, China and Korea - for whom modern science was, initially, an imported body of beliefs and practices. On this matter it is worth relating that Asia is now the 'gold medalist' for *Science & Education* article-downloads, edging out both North America and Europe.

The Regional chapters can minimise the extent to which the educational wheel has to be reinvented; provincial and national decision making can be informed by the successes and failures of what has occurred elsewhere. For each country one can see debates about curriculum construction and authority, about appropriate teacher education and its very possibility, and about appropriate assessment. These chapters are a contribution to Comparative Education, as well as to science and mathematics education. But for space and time constraints, other countries and regions could have been included; they have their own HPS&ST histories that could be told. Certainly more individual European countries could have been included – at least France, Spain, Greece and the Nordic countries.

The fourth, biographical studies, section is of special importance to the Handbook and to HPS&ST research. Current scholarship is part of a tradition that stretches back over a century, something not often enough appreciated. Too often the arguments, analyses and conceptual distinctions of important scholars of the past, which can be a source of enlightenment in the present, are neglected. Also lost is the good example of scholarship and engagement with educational issues, processes and institutions that such writers and researchers provide and that can inspire and be emulated.

In an effort to mitigate this tendency *Science & Education* in its early volumes reproduced each year a 'Golden Oldie', a good paper that had been published 40, 50, 60 years earlier. These included classic papers by Israel Scheffler, Robert S. Cohen, I. Bernard Cohen, John Dewey and Walter Jung. The idea was to show that a good argument or a useful conceptual distinction stands the test of time and can be fruitfully engaged with by current researchers. Newton famously remarked that he could see further because he stood upon the

shoulders of giants; this is also possible in education provided we know who and what has gone before. Unfortunately neither teacher education nor doctoral programmes do much to spread such knowledge, and consequent sense of engagement in a tradition.

Consider the opening pages of a 1929 text for science teachers where a successful science teacher is described as one who:

> knows his own subject . . . is widely read in other branches of science . . . knows how to teach . . . is able to express himself lucidly . . . is skilful in manipulation . . . is resourceful both at the demonstration table and in the laboratory . . . is a logician to his finger-tips . . . is something of a philosopher . . . is so far an historian that he can sit down with a crowd of [students] and talk to them about the personal equations, the lives, and the work of such geniuses as Galileo, Newton, Faraday and Darwin. More than this he is an enthusiast, full of faith in his own particular work. (F.W. Westaway, *Science Teaching*, 1929, p.3)

After eighty years of research and debate, it is a challenge to think of what else needs adding to this account. The author, Frederick W. Westaway, was a remarkable man who himself was something of a historian and philosopher with major books published in both fields; he was also a science teacher; and perhaps above all he was an HMI, a Her Majesty's Inspector for School Science. He did not live and work in an ivory tower, but was an administrator and held for decades a crucial bureaucratic position in UK education. He is all but unknown by current science education researchers. By good fortune in 1993 I stumbled over his 440-page 1929 book on the shelf of an Auckland second-hand book shop. The Handbook chapter on Westaway will do something to correct his undeserved neglect.

The five chapters in this section – on Mach, Dewey, Schwab, Westaway and Holmyard – deal with the foundation figures of HPS&ST scholarship. Chapter authors were asked to: explicate the view of HPS held by their subjects and how their views connected to then extant HPS positions; indicate how this HPS understanding had connection with educational practice; describe what impact the subject's writings had at the time; and provide some hindsight evaluation of the person's place in the history of science education. A demanding task, but marvellously well done here by the chapter authors.

Others who appealed to history and philosophy of science to illuminate theoretical, curricular and pedagogical issues in science and mathematics education could have been added to the section but space constraints intervened. Among these would be at least: James Conant, Arnold Arons, Martin Wagenschein, Walter Jung, Eino Kaila and Fabio Bevilacqua. Gerald Holton whose many HPS books and articles, HPS-informed physics texts and above all his long engagement in development and promotion of the Harvard Project Physics course, has a special place in the field of HPS&ST scholarship and would be added to the Biographical section if practicalities allowed. Many others had well developed HPS&ST ideas but less sustained educational engagements so were not considered for inclusion. These would include J.D. Bernal, Philipp Frank, Herbert Feigl and Martin Eger. In mathematics education comparable 'classics' lists can be provided of scholars who have consciously appealed to the history and philosophy of mathematics to address theoretical, curricular and pedagogical questions. Teachers, graduate students and professors can benefit from engaging with the writing of any of the researchers named here.

Writing

The Editorial for the first issue of *Science & Education* (1992) stated that the journal will: 'encourage clear and intelligible writing that is well argued and contains a minimum of jargon' (p.8). Frederick Westaway in his 1926 book *The Writing of Clear English* and George Orwell in his famous 1945 essay 'Politics and the English Language' both stressed the connection between clear writing and clear thinking. Too often in education, jargon and

lazy ‘eduspeak’ occurs; where it does, clear and useful communication, thinking and analysis is imperilled. Effort has been made to have the Handbook conform to ideals of good writing and clear-communication.

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Springer editorial staff should be thanked: Bernadette Ohmer for suggesting, encouraging and preparing the initial path for the project and Marianna Pascale for guiding it through its complex production stage. Inevitably with such a big project, one could expect tensions and disappointments, but pleasingly there have been few. Although time consuming, my editorial duties have been personally and professionally rewarding. I have learnt much by working with the large group of contributors from many countries and many disciplines. Much is owed to these scholars, and to the large group of reviewers who diligently commented on and corrected drafts of the chapters, and to the unsung copyeditors. Hopefully the writing and editorial labours have reinforced the importance of ‘laying out the past and current state of historical and philosophical research in science and mathematics education’, and have contributed usefully to graduate students and researchers who will advance the field.